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Engineering Standard Practice

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ELECTRONIC SYSTEMS AND EQUIPMENT

PRACTICE: **ESP 89**

ISSUE:. **4**

Engineering Standard Practice

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

TABLE OF CONTENTS

1.0 ELECTROMAGNETIC ENVIRONMENTAL EFFECTS . . . 1

1.1 Introduction: 1

1.2 Applicable Documents 1

1.3 Document Requirements 3

1.4 Electromagnetic Compatibility 8

1.4.1 General 8

1.4.2 Assessment of Criticality 9

1.4.2.1 High Intensity Radiated Fields 10

1.4.2.2 Lightning Indirect Effects 11

1.5 High Intensity Radiated Fields (HIRF) 12

1.5.1 Level A Requirements 12

1.5.1.1 Conducted Susceptibility (10 KHz to 400 MHz) . . . 13

1.5.1.2 Radiated Susceptibility (100 MHz to 18 GHz) . . . 14

1.5.1.3 Test Requirements 15

1.5.2 Level B Requirements 16

1.5.2.1 Conducted Susceptibility (10 KHz to 400 MHz) . . . 16

1.5.2.2 Radiated Susceptibility (100 MHz to 8 GHz) 16

1.5.2.3 Test Requirements 17

1.5.3 Level C Requirements 17

1.5.3.1 Conducted Susceptibility (10KHz to 400 MHz) . . . 18

1.5.3.2 Radiated Susceptibility (100 MHz to 8 GHz) 18

1.5.3.3 Test Requirements 18

1.5.4 Level D and E Requirements 19

1.5.5 Test Program Requirements 19

1.6 Lightning Protection 19

1.6.1 Lightning Direct Effects 19

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Engineering Standard Practice

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

TABLE OF CONTENTS

1.6.2 Lightning Indirect Effects 20
1.6.3 Lightning Verification Testing 32
1.6.3.1 Pin Testing 32
1.6.3.2 Cable Bundle Testing 32
1.6.3.3 Test Requirements 33
1.6.4 Test Program 34
1.6.5 External Lightning Environment 35
1.6.5.1 Indirect Effects 35
1.7 Electromagnetics Protection 36
1.7.1 Electrical Bonding and Grounding 36
1.7.2 Protective Devices 37
1.7.3 Shielding 37
1.7.4 Electrostatic Discharge Susceptibility (ESD) 37

Engineering Standard Practice

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

LIST OF TABLES

TABLE 1. Lightning Indirect Effects: Lightning EM Region 1 ETDL Cables Routed To/Within The Engine compartment, Nose and Main Landing Gear, Radome 23

TABLE 2. Lightning Indirect Effects: Lightning EM Region 2A ETDL Cables Routed Along Rear Spar and within Aft Nacelle .. 24

TABLE 3. Lightning Indirect Effects: Lightning EM Region 2B ETDL Cables Routed To/Within The Nose Equipment Bay, Aft Fuselage (Aft of Rear Pressure Bulkhead), Wing Front Spar 25

TABLE 4. Lightning Indirect Effects: Lightning EM Region 2C ETDL Cables Routed To/Within The Tailcone, Vertical Stabilizer and Horizontal Stabilizer 26

TABLE 5. Lightning Indirect Effects: Lightning EM Region 3A ETDL Cables Routed Behind The Instrument Panel and Cables (less than 7 m long) Routed Between Avionics Rack and Passenger Cabin 27

TABLE 6. Lightning Indirect Effects: Lightning EM Region 3B ETDL Cables Routed Within The Avionics Rack 28

TABLE 7. Lightning Indirect Effects: Lightning EM Region 3C ETDL Cables Routed Within the Fuselage Pressure Vessel Except EM Regions 3A and 3B 29

TABLE 8. LEVEL A CERTIFICATION TEST LEVELS 39

TABLE 9. LEVEL A NORMAL TEST LEVELS 40

Engineering Standard Practice

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

LIST OF TABLES

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LIST OF FIGURES

FIGURE 1. Lightning EM Regions 30
FIGURE 2. Lightning EM Regions 31
FIGURE 3. Probable Lightning Strike Distribution 41
FIGURE 4. Lightning Strike Zones - Dash-8 Series 400; Side View 42
FIGURE 5. Current Waveform 1 43
FIGURE 6. Voltage Waveform 2 43
FIGURE 7. Voltage/Current Waveform 3 44
FIGURE 8. Voltage Waveform 4 44
FIGURE 9. Current/Voltage Waveform 5A 45
FIGURE 10. Burst Components 46
FIGURE 11. Multiple Burst Waveform 47
FIGURE 12. Electrostatic Discharge (ESD) Test Setup 47
FIGURE 13. Electrostatic Discharge (ESD) Test Generator 48
FIGURE 14 . ESD Test Voltage Wavefor m 49
FIGURE 15. EM Region Interfaces 50
FIGURE 16. Proposed Set-up of Cable Bundle Test 51

Engineering Standard Practice

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

LIST OF FIGURES

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ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

1.0 ELECTROMAGNETIC ENVIRONMENTAL EFFECTS

1.1 Introduction:

DHC 8 Series 400 electrical and electronic equipment and systems must be designed to provide protection against the effects of Lightning Strike, High Intensity Radiated Fields (HIRF), Electromagnetic Interference, Triboelectric Charging and Electrostatic Discharge.

Electromagnetic compatibility requires that each system perform its intended function in the airplane electromagnetic environment, and that the operation of a given system does not degrade the performance of other airplane systems. The limits of emission and susceptibility thresholds contained in this document are a means of assuring that the design objectives will be achieved when compliant equipment is installed on an aircraft.

The document contains the electromagnetic compatibility requirements of electrical/electronic equipment selected for installation on the de Havilland DHC-8 Series 400 aircraft.

The requirements of this document, commencing at issue 4 also apply to the airframe components of the engine control system (FADEC and PEC). The airframe is defined as all components/cables of the engine control system located aft of the engine firewall including components/ cables located in the wing and fuselage as well as the cables located within the engine compartment routed from the PEC and FADEC to the engine firewall. The engine control system components/cables within the engine compartment forward of the firewall will continue to meet the requirements described in their respective de Havilland Technical Requirement Document, DTRD-8-002 and DTRD-8-003.

1.2 Applicable Documents

Documents listed form part of this Engineering Standard Practice to the extent specified below and to the extent specifically referenced in other paragraphs. If a document is referenced without any specific paragraph as being applicable, then the document is applicable in its entirety. Where a particular issue or revision of a document is specified in the text, no other issue or revision shall be used. Where no revision is mentioned, the latest issue or revision shall be used if not provided.

Government Documents

TCA SCA 95-07	de Havilland DHC-8 Series 400, High Intensity Radiated Fields
FAA AC 20-136	Protection of Aircraft Electrical/ Electronic Systems Against the Indirect Effects of Lightning
FAA AC 20-53A	FAA Advisory Circular: ‘Protection of Airplane Fuel Systems Against Lightning
FAA AC 20-107	Composite Aircraft Structure
JAA CRI F-01	Protection from the Effects of HIRF
JAA CRI F-03	Protection of the Effects of Lightning Strike: Indirect Effects
RTCA DO 160C	Environmental Conditions and Test Procedures for Airborne Equipment.
DOT/FAA/CT-83-3	User’s Manual for AC 20-53A Protection of Airplane Fuel Systems Against Fuel Vapor Ignition Due to Lightning.
DOT/FAA/CT-89/22	Aircraft Lightning Protection Hand-book
MIL-STD-1757	Lightning Qualification Test

	Techniques for Aerospace Vehicles and Hardware.
MIL-STD 461C	Electromagnetic Emissions and Susceptibility Requirements for the Control of Electromagnetic Energy
ESP 84	Dash 8 Series 400 Electromagnetics Control Plan
DTRD-8-002	de Havilland Technical Requirements Document for a Propulsion Engine Dash 8 Series 400 Aircraft
DTRD-8-003	de Havilland Technical Requirements Document for Propeller Dash 8 Series 400 Aircraft

1.3 Document Requirements

De Havilland will provide the Supplier with a DHC 8 Series 400 EMI/ HIRF/Lightning General Control Plan (ESP 84). The control plan will provide design standards to ensure a common design protection methodology for the DHC 8 Series 400 and to ensure that the DHC 8 Series 400 complies with the certification requirements applicable to Electromagnetic Effects as outlined within the Technical Requirements Document (DTRD).

The Supplier shall provide de Havilland with the following documentation.

1) EMI/HIRF and Lightning Control Plan.

2) EMI/HIRF and Lightning Assurance Plan

3) EMI/HIRF and Lightning Test Plan

4) EMI/HIRF and Lightning Test Report

1) EMI/HIRF and Lightning Control Plan

Using the certification requirements contained within the DTRD and ESP 89, as well as the design standards contained with the Electromagnetics General Control Plan (ESP 84), the Supplier shall provide a EMI/HIRF/

Lightning Control Plan for de Havilland approval. The Supplier shall update the control plan throughout the program as outlined below to reflect the current design and reflect all current EMC requirements levied upon the Supplier. The Supplier EMI/HIRF/Lightning Control Plan is a prerequisite to the Assurance Plan outlined in item 2.

The control plan shall provide the following information prior to the Preliminary Design Review:

a) Describe the design protection and verification methodology which the Supplier proposes to utilize to demonstrate compliance with the requirements of the Technical Requirements document and ESP 89.

b) Describe the drawing control policy which verifies the incorporation of electromagnetics protection as well as the change board policy to control configuration.

c) Describe the organizational responsibilities with respect to EMI/HIRF/Lightning including names of individuals responsible for EMC design, analysis and documentation. A schedule of EMC events and milestones shall be included and a summary of EMC requirements passed to or levied upon subcontractors by the Supplier.

The control plan shall provide the following information prior to the Critical Design Review.

The control plan shall be updated to include detailed design protection and verification methodology as outlined in a) through g) of the Assurance Plan. Provide analysis and/or development test data to substantiate the design protection methodologies.

2) EMI/HIRF and Lightning Assurance Plan

Prior to certification, the Supplier shall provide a EMI/HIRF/ Lightning Assurance Plan which details the overall approach, design procedures and techniques which have been incorporated to meet the contractual EMI/HIRF/Lightning requirements specified in the DTRD and ESP 89. As a minimum, the plan shall address the following:

a) Organizational responsibilities with respect to EMI/HIRF/

Lightning shall be provided including the names of individuals responsible for EMC design, analysis and documentation. All applicable EMC documentation shall be identified in the Plan, along with EMC specifications which are used in the design.

b) Operational parameters of the system and its intended installation shall be described. Identify which portions of the system are contained within the various component units, the location of the units and mounting considerations. Provide a detailed description of the operation of the system.

c) A summary of mechanical design as related to EMC shall be provided in the Plan. Describe procedures and methods including materials and treatments which are used for the purpose of attenuating electromagnetic emissions and/or reducing susceptibilities of systems/equipment to the specified electromagnetic threats. Describe internal shielding, RF gasketing, filtering and suppression devices used to achieve compliance.

Describe the filtering characteristics of power line filters and filter pins as well as the characteristics of suppression devices (tranzorbs etc.). Describe the location and physical characteristics of possible apertures including electrical connectors, ventilation ports and display screens as well as the protection methodologies used to achieve compliance.

d) Describe the wire and cable harness design protection required to minimize emissions and susceptibilities, including the wire type, wire treatment, wire routing and shielding/shield termination methodology. Describe the characteristics of wire/ cable shields including the transfer impedance. Identify circuit interfaces and wires in terms of being either susceptible to EMI or capable of being a source of interference. Describe wire separation and any additional protection methodology (i.e. clamping diodes) required to achieve compliance. Technical criteria is required to justify the use of cable shields and filter pins within the design.

e) Describe the bonding and grounding methodology used including electrical bonding requirements for equipment, power lines, signal lines and power distribution within or between individual units of a system. Provide a bonding and grounding diagram of the system including equipment and interfaces. Describe any software techniques including software filters used to achieve compliance.

f) Candidate sources of interference or susceptibility should be identified by the Supplier. The Plan should provide a summary of the clock frequencies, data rates and frequencies of RF carriers utilized in the design.

g) The Supplier shall update the Assurance Plan throughout the program to reflect the current design and reflect all current EMC requirements levied upon the Supplier.

h) Describe any in-service maintenance tasks and procedures which may be required to ensure the continued airworthiness of electrical and electronic system/equipment in the electromagnetic environment. Components which may require maintenance include cable shielding, conductive gaskets, conductive coatings, suppression/filter devices, bonding straps. Define the acceptable level of protection design degradation before repair action is required.

3) EMI/HIRF and Lightning Test Plan

A detailed EMI/HIRF and Lightning test plan shall be submitted for de Havilland approval at least 90 days prior to conducting the certification tests. The test plan shall include the following as a minimum:

a) List of tests to be performed and the specific wires, circuit interfaces and equipment to be tested. The wires are to be identified by connector pin number and function. Any wires not tested must be approved by de Havilland.

b) Description of all equipment operating modes to be tested. Any operating modes not evaluated during any specific test must be approved by de Havilland. Identify clock frequencies and data rates.

c) Methods and location of monitoring equipment as well as the performance and quantitative standards for determining the pass/fail criteria.

d) Specific and detailed electrical test setup diagrams (conformity/ controlled layout drawing) which clearly show and identify power wiring, interconnect wiring, ground wires, circuit loads, wiring configuration (twisted, shielded, shield grounds, wire lengths, connector/backshell hardware) spatial layout, production breaks, equipment under test and electrical bonding methodology.

e) A detailed description of the test procedure including the test levels.

f) A detailed description of the test facility and test equipment including test rig vs. bench testing and support equipment.

4) EMI/HIRF and Lightning Test Report

A detailed EMI/HIRF and Lightning test report is required to be submitted to de Havilland within 30 days following test completion. As a minimum, the report shall contain the following: (Note:- any deviations from the test plan must be approved by de Havilland prior to testing).

a) Summary of tests conducted and results obtained.

b) List of test equipment used including calibration date.

c) Dimensional sketch and photograph of test setups that clearly identify all equipment and interconnections under test.

d) Equipment identification, including complete nomenclature, manufacturer, part numbers, software configuration (if applicable) and serial numbers.

e) Tabulated test data

f) Graphs, oscillograms etc. showing the test results. Test limits and/or threat levels shall be shown such that compliance or noncompliance is evident. Photographs from a spectrum

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

analyzer are acceptable providing the test limits are shown.

g) Description of modifications to equipment incorporated during the test.

h) List of antenna correction factors, current probes transfer impedances and other test equipment characteristics and correction factors used during the test program.

1.4 Electromagnetic Compatibility

1.4.1 General

Aircraft system electrics/electronics shall comply with the electromagnetic compatibility requirements as listed below.

Magnetic Effects

Electrical/Electronic systems and equipment shall comply with the magnetic effects requirements as specified in RTCA DO 160C Section 15 Category Z.

Voltage Spike

Electrical/Electronic systems and equipment shall operate without degradation of performance, malfunction or undesirable effects when subjected to the voltage spike requirements as specified in RTCA DO 160C section 17 Category A.

Audio Frequency Conducted Susceptibility

Electrical/Electronic systems and equipment shall operate without degradation of performance, malfunction or undesirable effects when subjected to the requirements as specified in RTCA DO 160C Section 18 Category Z.

Induced Signal Susceptibility

Electrical/Electronic systems and equipment shall operate without degradation of performance malfunction or undesirable effects when subjected to the requirements as specified in RTCA DO 160C Section 19 Category Z.

Radio Frequency Susceptibility

Electrical/Electronic systems and equipment shall comply with the radio frequency susceptibility requirements specified in section 1.5 of ESP 89 (High Intensity Radiated Fields).

Emission of Radio Frequency Energy

Electrical/Electronic systems and equipment shall comply with the radio frequency emission requirements as specified in RTCA DO 160C Section 21 Category Z.

Lightning Induced Transient Susceptibility

Electrical/Electronic systems and equipment shall comply with the lightning transient susceptibility requirements specified in section 1.6 of ESP 89 (Lightning Protection).

Lightning Direct Effects

Electrical/Electronic systems and equipment shall comply with the lightning direct effects requirements specified in section 1.6 of ESP 89 (Lightning Protection).

Conducted Emissions, Spikes

Electrical/Electronic systems and equipment shall comply with the conducted emission requirements as specified in MIL-STD-461C section CE07.

Test procedures and results shall be documented by the Supplier and provided to de Havilland. Shielded leads shall not be used in the test set-up unless they have been specified for use in the intended installation. Any and all observable effects exhibited by equipment during testing shall be reported to de Havilland, and the acceptability of these effects shall be agreed upon by de Havilland.

1.4.2 Assessment of Criticality

The requirement for demonstration of compliance to the regulatory requirements/special conditions for Lightning Indirect Effects and High Intensity Radiated Fields (HIRF) are related to the functional criticality of the electrical/electronic systems and equipment. The degree and complexity of aircraft level tests, system bench tests and equipment level tests are determined by the functional criticality of each system.

1.4.2.1 High Intensity Radiated Fields

The degree and complexity of aircraft level tests, system bench tests and equipment level tests are determined by the functional criticality of each system. The HIRF failure condition categories listed below are included to assist the Supplier in the use of this document.

a) Catastrophic:

Failure conditions which would prevent continued safe flight and landing.

b) Hazardous/Severe Major:

Failure conditions which would reduce the capability of the aircraft or the ability of the flight crew to cope with adverse operating conditions to an extent that there would be:

i) A large reduction in safety margins or functional capabilities.

ii) Physical distress or higher workload such that the flight crew could not be relied upon to perform their tasks accurately or completely, or

iii) Serious injury to a relatively small number of occupants.

c) Major:

Failure conditions which would reduce the capability of the aircraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example, a significant reduction in safety margins or functional capabilities, a significant increase in crew workload or in conditions impairing crew efficiency or discomfort to occupants possibly including injuries.

d) Minor:

Failure conditions which would not significantly reduce aircraft safety, and which involve crew actions that are well within their capabilities. Minor failure conditions include, for example, a slight reduction in safety margins or functional capabilities, slight increase in crew workload, such as routine flight plan changes or some inconvenience to operators.

e) No Effect:

Failure conditions which do not affect the operational capability of the aircraft or increase crew workload.

The HIRF test requirements are related to the failure condition category. The definition of these test requirements are outlined below:

a) **Level A**: Electrical and electronic systems whose failure would contribute to a failure of function resulting in a catastrophic failure condition for the aircraft.

b) **Level B:** Electrical and electronic systems whose failure would cause or contribute to a failure of function resulting in a hazardous/severe major failure condition for the aircraft.

c) **Level C:** Electrical and electronic systems whose failure would cause or contribute to a failure of function resulting in a major failure condition for the aircraft.

d) **Level D:** Electrical and electronic systems whose failure would cause or contribute to a failure of function resulting in a minor failure condition for the aircraft.

e) **Level E:** Electrical and electronic systems whose failure would cause or contribute to a failure of function resulting in no effect on aircraft operational capability or pilot workload.

1.4.2.2 Lightning Indirect Effects

Aircraft electrics/electronics systems performing critical and essential functions shall comply with the following certification requirements:

Each electrical and electronic system which performs critical functions must be designed and installed to ensure that the operation

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

and operational capabilities of these systems to perform critical functions are not affected during and after the airplane is exposed to the external lightning environment associated with “Indirect Effects.”(section 1.6.5)

Each essential function of an electrical and electronic system must be designed and installed to ensure that the essential function can be recovered in a timely manner after the airplane has been exposed to the external lightning environment associated with “Indirect Effects”.(section 1.6.5)

Critical Function: A function whose failure would contribute to or cause a condition that would prevent the continued safe flight and landing of the airplane.

Essential Function: A function whose failure would contribute to or cause a condition that would reduce the capability of the airplane or the ability of the flight crew to cope with adverse operating conditions.

The following failure condition matrix provides a cross reference guideline with respect to the terminology used to describe the systems criticality applicable to Lightning and HIRF.

FAILURE CONDITION	NOMENCLATURE OF FUNCTIONS
MINOR	NONESSENTIAL
MAJOR	ESSENTIAL
SEVERE MAJOR	ESSENTIAL
CATASTROPHIC	CRITICAL

1.5 High Intensity Radiated Fields (HIRF)

Aircraft electrical and electronic systems, equipment and installations considered separately and in relation to other systems must be designed and installed to comply with the following requirements.

1.5.1 Level A Requirements

Systems categorized as Level A shall comply with the requirements outlined below. The HIRF test levels represent the HIRF environment to which aircraft equipment and cables will be exposed. The test level requirements are divided into Certification test levels and Normal test levels.

The Certification test levels are based on the TCA Special Condition SCA 95-07 (Draft) minimum threat level and the JAA Document CRI F-01 Certification HIRF Environment. Each function whose failure would prevent the continued safe flight and landing of the aircraft, must not be adversely affected [1] during and after the time the system performing such function is exposed to the Certification test levels defined in sections 1.5.1.1 and 1.5.1.2. If the function is provided by multiple systems, then loss of the system or systems during exposure to the Certification test levels shall not result in a loss of function. After the system or systems exposure to the Certification test levels, each affected system that performs these functions shall automatically recover normal operation.

The Normal test levels are based on the JAA Document CRI F-01 Normal HIRF Environment. Each system that performs Level A functions must not be adversely affected during and after exposure to the Normal test levels defined in sections 1.5.1.1and 1.5.1.2.

1.5.1.1 Conducted Susceptibility (10 KHz to 400 MHz)

Conducted susceptibility testing shall be carried out from 10 kHz to 400 MHz as outlined below:

a) Certification test levels:
150 mA from 500 KHz to 400 MHz
Decreasing log linearly to 3 mA from 500 KHz to 10 KHz

b) Normal test levels:
75 mA from 500KHz to 400 MHz
Decreasing log linearly to 1.5 mA from 500 KHz to 10 KHz

A summary of the certification test levels is provided in Tables 8 and 9.

1. Adverse Effects: a response of a system that results in an undesirable operation of an aircraft system or subsystem.

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

Cable bundle test requirements are outlined below:

a. Each cable bundle shall be tested as a whole, connector by connector, excluding ground wires (associated with the equipment under test) which are grounded to structure locally to the equipment.

b. Primary power lines shall be tested individually with the test current being injected and monitored on each line.

c) For systems with built in redundancy, simultaneous injection on several cable bundles may be required.

The tests shall be carried out using the following modulations. Dwell at internal modulation, data and clock frequencies.

a. Continuous Wave (CW) from 10KHz to 400 MHz

b. 1KHz square wave modulation of at least 90% depth with a superimposed 1Hz square modulation of at least 90% depth for frequencies from 2 MHz to 30 MHz.

c. Apply other modulations that may be related to the clock, data or processing frequencies of the equipment under test.

1.5.1.2 Radiated Susceptibility (100 MHz to 18 GHz)

Systems shall be tested to the Certification and Normal test levels defined in Tables 8 and 9 respectively for frequencies between 100 MHz and 18 GHz. The Certification and Normal test levels include average and peak field requirements.

Average field testing in the frequency band from 100 MHz to 18 GHz shall be carried out using the following modulations:

a. Continous Wave (CW) from 100 MHz to 18 GHz.

b. 1KHz square wave modulation of at least 90% depth from 100 MHz to 18 GHz

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

Peak field testing in the frequency band between 400 MHz and 18 GHz shall be carried out using the following modulations:

a. 1 KHz pulse modulation of at least 90% depth with at 1% duty cycle (10 microsecond pulse width). In addition, the signal shall be switched “on” and “off” at a rate of 1 Hz with a 200 millisecond “on” time and an 800 millisecond “off” time.

b. Apply other modulations that may be related to the clock, data or processing frequencies of the equipment under test.

For both the average and peak field testing dwell at internal modulation, data and clock frequencies.

1.5.1.3 Test Requirements

Equipment shall be tested in accordance with procedures of DO-160C/ ED14, Chapter 20 (May 13, 1993 or later issue). However DO-160/ ED14 are minimum performance standards and as such do not provide the degree of thoroughness that are required for systems categorized as performing a Level A functions.

HIRF testing shall be carried out closed loop on a completely operational system. The equipment Supplier must carry out a “systems test” on all equipment comprising the system including interconnecting cable harnesses manufactured by both the equipment Supplier and airframe manufacturer. Any interfacing equipment which may be the responsibility of “other” equipment Suppliers must be included in the test or electrically simulated. The Supplier is responsible for fabricating the cable harness required for certification testing.

The laboratory test set-up shall represent all aspects of the aircraft installation including cable bundle composition (including shields and shield terminations), installation policy, and equipment bonding techniques.

The system shall be tested in the various operational states (including input sensors) to ensure the system is evaluated at its maximum sensitivity.

After demonstrating system acceptance to the levels specified above, the test levels shall be increased to determine frequency bands and levels at which the system begins to demonstrate adverse effects. All

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

adverse effects including the test levels and frequencies at which they occur shall be documented by the Supplier and provided to de Havilland.

1.5.2 Level B Requirements

Each system that performs a function, whose failure would cause a Hazardous/Severe Major effect, must not be adversely affected when the equipment providing these functions is tested to Category R of RTCA DO 160C section 20 (May 13, 1993 or later issue) as outlined below.

1.5.2.1 Conducted Susceptibility (10 KHz to 400 MHz)

Conducted susceptibility testing is required from 10KHz to 400MHz at the following current levels:

30 ma from 400MHz to 500KHz
Decreasing log linearly to 0.6 ma from 500KHz to 10KHz

Testing shall be carried out with the following modulations.

a) Continuous Wave (CW)

b) 1KHz square wave modulation at greater than 90% depth.

Cable bundle test requirements are outlined below:

a. Each cable bundle shall be tested as a whole connector by connector excluding ground wires (associated with the equipment under test) which are grounded to structure locally to the equipment.

b. Primary power lines shall be tested individually with the test current being injected and monitored on each line.

1.5.2.2 Radiated Susceptibility (100 MHz to 8 GHz)

Radiated susceptibility testing is required from 100 MHz to 400 MHz

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

at a field level of 20 volts per meter peak rms. Testing shall be carried out at the following modulations:

a. Continuous Wave (CW)

1KHz square wave modulation at greater than 90% depth.

b. Radiated susceptibility testing is required from 400 MHz to 8 GHz at the following field levels and modulations:

c. 150 volts per meter peak rms with a modulation of 0.1% duty cycle with a 1 kHz PRF. The signal should, in addition, be switched on and off at a rate of 1 Hz with a duty cycle of 50% to simulate the effect of scanning antennas. The depth of modulation should be at least 90%.

d. 28 volts per meter peak rms with a modulation of 50% duty cycle with a 1 kHz PRF. The signal should, in addition be switched on and off at a rate of 1 Hz with a duty cycle of 50% to simulate the effect of scanning antennas. The depth of modulation should be at least 90%.

OR

Alternatively tests c) and d) may be replaced with a single test as follows:

a. 150 volts per meter peak rms with a modulation of 4% duty cycle with a 1 kHz PRF. The signal should, in addition, be switched on and off at rate of 1 Hz with a duty cycle of 50% to simulate the effect of scanning antennas. The depth of modulation should be at least 90%.

1.5.2.3 Test Requirements

Equipment which performs Level B functions may be tested in accordance with the test procedures in DO-160C/ED14, Chapter 20 (May 13, 1993 or later issue).

1.5.3 Level C Requirements

Each system that performs a function, whose failure would cause a Major effect shall not be adversely affected when the equipment

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

providing these functions is tested to Category T of RTCA DO160C Section 20 (May 13, 1993 Issue) as outlined below.

1.5.3.1 Conducted Susceptibility (10KHz to 400 MHz)

Conducted susceptibility testing is required from 10KHz to 400MHz at the following current levels:

7.5 ma from 400MHz to 500KHz
Decreasing log linearly to 0.15 ma from 500KHz to 10KHz.

Testing shall be carried out with the following modulations.

a) Continuous Wave (CW)

b) 1KHz square wave modulation at greater than 90% depth

Cable bundle test requirements are outlined below:

a. Each cable bundle shall be tested as a whole connector by connector excluding ground wires (associated with the equipment under test) which are grounded to structure locally to the equipment.

b. Primary power lines shall be tested individually with the test current being injected and monitored on each line.

1.5.3.2 Radiated Susceptibility (100 MHz to 8 GHz)

Radiated susceptibility testing is required from 100 MHz to 8 GHz at a level of 5 volts per meter peak rms. Testing shall be carried out at the following modulations:

a. 1 kHz square wave modulation of at least 90% depth for frequencies between 100 MHz to 8 GHz

1.5.3.3 Test Requirements

Equipment which performs Level C functions may be tested in accordance with the test procedures in DO-160C/ED14, Chapter 20 (May 13, 1993 or later issue).

1.5.4 Level D and E Requirements

It is a de Havilland requirement that equipment categorized as Level D and E shall not be adversely affected when tested to Category T of RTCA DO160C Section 20 (May 13, 1993 or later issue) within the frequency range of 10 KHz to 1.215 GHz.

Cable bundle test requirements are outlined below:

a. Each cable bundle shall be tested as a whole connector by connector excluding ground wires (associated with the equipment under test) which are grounded to structure locally to the equipment.

b. Primary power lines shall be tested individually with the test current being injected and monitored on each line.

Equipment categorized as Level D and E may be tested in accordance with the test procedures in DO-160C/ED14, Chapter 20 (May 13, 1993 or later issue).

1.5.5 Test Program Requirements

The Supplier shall provide a HIRF test plan defining the test procedures, proof of test article conformity and any supporting information to be used to demonstrate compliance with the HIRF requirements. Test article conformity includes a controlled layout drawing to document all the electrical and mechanical details of the test article including the test harness and equipment comprising the test article. Any deviation from the aircraft installation must be documented. The test results shall be documented by the Supplier and provided to de Havilland. Any and all observable effects exhibited by the equipment during testing shall be reported to de Havilland and the acceptability of these effects shall be agreed upon by de Havilland.

1.6 Lightning Protection

1.6.1 Lightning Direct Effects

Electrical and electronic equipment designed with externally mounted electrical components must be designed and installed to minimize the physical damage effects of a lightning strike as well as minimize the time and cost of repair when tested to the requirements of RTCA DO 160C Section 23.

It must be verified by test or analysis that externally mounted electrical components such as External Lights, Air Data Probes, Temperature Sensors, AOA Vanes, Ice Detectors, De-Ice/Anti-Ice Heater Circuits and Antennas are designed such that there is no injection of damaging lightning voltage or current directly into the electrical elements. Any transients on the connected cables must be measured and their effect on connected equipment/wiring evaluated to ensure continued safe flight and landing of the aircraft. In addition, it must be verified by a hi-pot or pin test that the voltage withstand level between the external surface of the electrical component and the internal electrical circuitry is greater than 750 volts.

The equipment must be tested (or analysis) with the lightning waveforms corresponding to the lightning strike zone in which the external equipment is located (Ref: RTCA DO160C Section 23). The lightning strike zones for the DHC-8 Series 400 are shown in figures 3 and 4.

1.6.2 Lightning Indirect Effects

Aircraft electrics/electronics systems performing critical and essential functions shall comply with the requirements described below.

The test levels specified in Tables 1 to 7 represent the Equipment Transient Design Levels (ETDL) defined as the peak amplitude together with an associated waveform to which critical and essential system electrics/electronics shall be qualified. These values are based on the external lightning environment defined in section 1.6.4. The lightning test waveforms are shown in Figures 5 - 9.

Each critical function of an electrical and electronic system must be designed and installed to ensure that the critical function is not adversely affected during and after system testing to the Multiple Stroke and Multiple Burst amplitude and waveforms specified.

Each system that performs critical functions shall automatically recover normal operation immediately following the lightning test unless this conflicts with other operational or functional requirements of that system.

Each essential function of an electrical and electronic system must be designed and installed to ensure that the essential function can be recovered in a timely manner after system testing to the Multiple Stroke and Multiple Burst amplitude and waveforms specified.

Each system performing critical and essential functions shall be designed and tested to withstand pin injection ETDL levels between each pin and equipment case ground connection for the voltage/ current levels specified.

To assist the Supplier with the lightning analysis, the aircraft has been classified into seven electromagnetic regions shown in Figures 1 and 2. Electrical/electronic systems including equipment and cable harnesses shall be designed and tested in accordance with the electromagnetic environment in which the equipment and cable harnesses are located.

Electromagnetic (EM) Regions (Figures 1 and 2):

Equipment and cable harnesses associated with systems performing critical and essential functions must be tested to the Equpment Transient Design Levels (ETDL) associated with the lightning EM Region in which the equipment and cable harnesses are located (Figures 1 and 2). The cable bundle and pin test levels associated with the following lightning EM Regions are provided in Tables 1 to 7.

1. EM Region 1: (Table 1)

i. Engine compartment of the nacelle

ii. Nose and main landing gear

iii. Nose radome

2. EM Region 2:

i. EM Region 2A: (Table 2)

a. Wing rear spar/Aft Nacelle

ii EM Region 2B: (Table 3)

a. Nose Equipment Bay

b. Aft fuselage (aft of the rear pressure bulkhead)

c. Wing front spar

iii. EM Region 2C (Table 4)

a. Tailcone

b. Vertical stabilizer

c. Horizontal stabilizer

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

3. EM Region 3:

i. EM Region 3A: (Table 5)

a. Instrument panel

b. Cabin (Wires less than 7 meters long routed between X-18.0 and X236.0).

ii EM Region 3B: (Table 6)

a. Avionics Rack

iii. EM Region 3C (Table 7)

a. All remaining areas within fuselage pressure vessel *excluding* EM Regions 3A and 3B.

Tables 1 to 7: Equipment Transient Design Levels (EDTL) Systems which performs Critical and Essential Functions

ESP 89 Issue 4 introduces cable bundle and pin test levels for *unshielded* wiring. The cable bundle and pin test levels provided in ESP 89 Issue 3 were based on *shielded* wiring for EM Region 1 and 2. In other words, ESP 89 issue 3 specified test levels which accounted for the effect of the shield. *Critical and Essential systems wiring routed outside of the fuselage pressure vessel (EM Regions 1 and 2) must be shielded*[1].

ESP 89 Issue 4 specifies levels for unshielded wiring to emphasize the fact that if critical and essential systems wiring routed outside the fuselage pressure vessel is not shielded, the test levels may be significantly higher.

1. Memo D-3612/RK/96-414 dated January 26, 1996

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

TABLE 1. Lightning Indirect Effects: Lightning EM Region 1 ETDL Cables Routed To/Within The Engine compartment, Nose and Main Landing Gear, Radome

REGION	CABLE ROUTING	REQUIREMENT	WAVEFORM	VOLTAGE REQUIREMENT
1	All cables within this region	Multiple Stroke Cable Bundle Shielded	1	10.000 I_T (Note 1)
1	All cables within this region	Multiple Stroke Cable Bundle Shielded‘	3 (1 and 10 MHz)	3200 V_L / 640 I_T
1	All cables within this region	Multiple Stroke Cable Bundle Unshielded	4	5000 V_T / 10,000 I_L (Note 3)
1	All cables within this region	Multiple Stroke Cable Bundle Unshielded	3 (1 and 10 MHz)	3200 V_T / 640I_L (Note 3)
1	All cables within this region	Multiple Burst Cable Bundle Shielded	3 (1 and 10 MHz)	3200 V_L/ 500 I_T (Note 2)
1	All cables within this region	Multiple Burst Cable Bundle Unshielded	3 (1 and 10 MHz)	3200 V_t / 500 I_L
1	All cables within this region	Single Stroke Pin injection Shielded	4	750 V_{oc} / 150 I_{sc}
1	All cables within this region	Single Stroke Pin injection Shielded	3 (1 MHz)	1500 V_{oc} / 60 I_{sc}
1	All cables within this region	Single stroke Pin injection Unshielded	4	5000 $V_{oc\ /}$ 1000 I_{sc}
1	All cables within this region	Single Stroke Pin injection Unshielded	3 (1 MHz)	3200 V_{oc} / 128 I_{sc}

Note 1: Assume 1000 A per shielded twisted pair or low impedance wire to a maximum of 10,000 A.

Cables routed along the nose and main landing gear must be tested to 10,000 A.

Low impedance wire is defined as any wire with an impedance of 100 ohms or less at frequencies below 10KHz.

Note 2: Multiple Burst Testing may be carried out using waveform 3 or waveform 1. If the test levels cannot be attained, disconnect all shields at both ends and reduce the test levels by a factor of 10.

Note 3: When testing power leads as a separate cable, ensure that corresponding short circuit current (Isc) in each power wire is not exceeded.

General Notes:

a. Shielded Cable Bundle is defined as cable bundle which contains one or more shields. Such cable bundle may-contain some unshielded wires.

b. Unshielded Cable Bundle is defined as a cable bundle which contains no shields

c. Pin Injection shielded refers to the test level applicable to a shielded wire

d. Pin Injection unshielded refers to the test level applicable to an unshielded wire

e. V_T represents the test voltage level in volts and I_T represents the test current level in amperes.

f. V_L and I_L represent the voltage and current limits intended to prevent over-stressing the EUT beyond require-ments.

g. V_{oc} and I_{sc} represent the open circuit voltage and short circuit current respectively.

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

TABLE 2. Lightning Indirect Effects: Lightning EM Region 2A ETDL Cables Routed Along Wing Rear Spar and within Aft Nacelle

REGION	CABLE ROUTING	REQUIREMENT	WAVEFORM	VOLTAGE REQUIREMENT
2A	All cables within this region	Multiple Stroke Cable Bundle Shielded	1	3200 I_T (Note 1)
2A	All cables within this region	Multiple Stroke Cable Bundle Shielded‘	3 (1 and 10 MHz)	3200 V_L / 640 I_T
2A	All cables within this region	Multiple Stroke Cable Bundle Unshielded	4	1600 V_T / 3200 I_L (Note 3)
2A	All cables within this region	Multiple Stroke Cable Bundle Unshielded	3 (1 and 10 MHz)	3200 V_T/ 640I_L (Note 3)
2A	All cables within this region	Multiple Burst Cable Bundle Shielded	3 (1 and 10 MHz)	3200 V_L / 160 I_T (Note 2)
2A	All cables within this region	Multiple Burst Cable Bundle Unshielded	3 (1 and 10 MHz)	3200 V_T / 160 I_L
2A	All cables within this region	Single Stroke Pin injection Shielded	4	750 V_{oc} / 150 I_{sc}
2A	All cables within this region	Single Stroke Pin injection Shielded	3 (1 MHz)	1500 V_{oc} / 60 I_{sc}
2A	All cables within this region	Single Stroke Pin injection Unshielded	4	1600 V_{oc} / 320 I_{sc}
2A	All cables within this region	Single Stroke Pin injection Unshielded	3 (1 MHz)	3200 V_{oc} / 128 I_{sc}

Note 1: Assume 320 A per shielded twisted pair or low impedance wire to a maximum of 3200 A.

Low impedance wire is defined as any wire with an impedance of 100 ohms or less at frequencies below 10KHz.

Note 2: Multiple Burst Testing may be carried out using waveform 3 or waveform 1. If the test levels cannot be attained, disconnect all shields at both ends and reduce the test levels by a factor of 10.

Note 3: When testing power leads as a separate cable, ensure that corresponding short circuit current (Isc) in each power wire is not exceeded.

General Notes:

a. Shielded Cable Bundle is defined as cable bundle which contains one or more shields. Such cable bundle may contain some unshielded wires.

b. Unshielded Cable Bundle is defined as a cable bundle which contains no shields

c. Pin Injection shielded refers to the test level applicable to a shielded wire

d. Pin Injection unshielded refers to the test level applicable to an unshielded wire

e. V_T represents the test voltage level in volts and I_T represents the test current level in amperes.

f. V_L and I_L represent the voltage and current limits intended to prevent over-stressing the EUT beyond requirements.

g. V_{oc} and I_{sc} represent the open circuit voltage and short circuit current respectively

TABLE 3. Lightning Indirect Effects: Lightning EM Region 2B ETDL Cables Routed To/Within The Nose Equipment Bay, Aft Fuselage (Aft of Rear Pressure Bulkhead), Wing Front Spar

REGION	CABLE ROUTING	REQUIREMENT	WAVEFORM	VOLTAGE REQUIREMENT
2B	All cables within this region	Multiple Stroke Cable Bundle Shielded	1	1500 I_T (Note 1)
2B	All cables within this region	Multiple Stroke Cable Bundle Shielded‘	3 (1 and 10 MHz)	1500 V_L / 300 I_T
2B	All cables within this region	Multiple Stroke Cable Bundle Unshielded	4	750 V_T / 1500 I_L
2B	All cables within this region	Multiple Stroke Cable Bundle Unshielded	3 (1 and 10 MHz)	1500 V_T / 300 I_L (Note 2)
2B	All cables within this region	Multiple Burst Cable Bundle Shielded	3 (1 and 10 MHz)	1500 V_L / 60 I_T
2B	All cables within this region	Multiple Burst Cable Bundle Unshielded	3 (1 and 10 MHz)	1500 V_T / 60 I_L
2B	All cables within this region	Single Stroke Pin injection Shielded	4	300 V_{oc} / 60 I_{sc}
2B	All cables within this region	Single Stroke Pin injection Shielded	3 (1 MHz)	600 V_{oc} / 24 I_{sc}
2B	All cables within this region including 28 volt power wire	Single Stroke Pin injection Unshielded	4	750 V_{oc} / 150 I_{sc}
2B	All cables within this region including 28 volt power wire	Single Stroke Pin injection Unshielded	3 (1 MHz)	1500 V_{oc} / 60I_{sc}

Note 1: Assume 150 A per shielded twisted pair or low impedance wire to a maximum of 1500 A.

Low impedance wire is defined as any wire with an impedance of 100 ohms or less at frequencies below 10KHz.

Note 2: When testing power leads as a separate cable, ensure that corresponding short circuit current (Isc) in each power wire is not exceeded.

General Notes:

a. Shielded Cable Bundle is defined as cable bundle which contains one or more shields. Such cable bundle may contain some unshielded wires.

b. Unshielded Cable Bundle is defined as a cable bundle which contains no shields

c. Pin Injection shielded refers to the test level applicable to a shielded wire

d. Pin Injection unshielded refers to the test level applicable to an unshielded wire

e. V_T represents the test voltage level in volts and I_T represents the test current level in amperes.

f. V_L and I_L represent the voltage and current limits intended to prevent over-stressing the EUT beyond requirements.

g. V_{oc} and I_{sc} represent the open circuit voltage and short circuit current respectively

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

TABLE 4. Lightning Indirect Effects: Lightning EM Region 2C ETDL Cables Routed To/Within The Tailcone, Vertical Stabilizer and Horizontal Stabilizer

REGION	CABLE ROUTING	REQUIREMENT	WAVEFORM	VOLTAGE REQUIREMENT
2C	All cables within this region	Multiple Stroke Cable Bundle Shielded	1	1500 I_T (Note 1)
2C	All cables within this region	Multiple Stroke Cable Bundle Shielded‘	3 (1 and 10 MHz)	1500 V_L / 300 I_T
2C	All cables within this region	Multiple Stroke Cable Bundle Unshielded	4	750 V_T / 1500 I_L (Note 2)
2C	All cables within this region	Multiple Stroke Cable Bundle Unshielded	3 (1 and 10 MHz)	1500 V_T / 300 I_L (Note 2)
2C	All cables within this region	Multiple Burst Cable Bundle Shielded	3 (1 and 10 MHz)	1500 V_L / 60 I_T
2C	All cables within this region	Multiple Burst Cable Bundle Unshielded	3 (1 and 10 MHz)	1500 V_T / 60 I_L
2C	All cables within this region	Single Stroke Pin injection Shielded	4	750 V_{oc} / 150 I_{sc}
2C	All cables within this region	Single Stroke Pin injection Shielded	3 (1 MHz)	1500 V_{oc} / 60 I_{sc}
2C	All cables within this region	Single Stroke Pin injection Unshielded	4	750 V_{oc} / 150 I_{sc}
2C	All cables within this region	Single Stroke Pin injection Unshielded	3 (1 MHz)	1500 V_{oc} / 60I_{sc}

Note 1: Assume 150 A per shielded twisted pair or low impedance wire to a maximum of 1500 A.

Low impedance wire is defined as any wire with an impedance of 100 ohms or less at frequencies below 10KHz.

Note 2: When testing power leads as a separate cable, ensure that corresponding short circuit current (Isc) in each power wire is not exceeded.

General Notes:

a. Shielded Cable Bundle is defined as cable bundle which contains one or more shields. Such cable bundle may contain some unshielded wires.

b. Unshielded Cable Bundle is defined as a cable bundle which contains no shields

c. Pin Injection shielded refers to the test level applicable to a shielded wire

d. Pin Injection unshielded refers to the test level applicable to an unshielded wire

e. V_T represents the test voltage level in volts and I_T represents the test current level in amperes.

f. V_L and I_L represent the voltage and current limits intended to prevent over-stressing the EUT beyond requirements.

g. V_{oc} and I_{sc} represent the open circuit voltage and short circuit current respectively

TABLE 5. Lightning Indirect Effects: Lightning EM Region 3A ETDL Cables Routed Behind The Instrument Panel and Cables (less than 7 m long) Routed Between Avionics Rack and Passenger Cabin

REGION	CABLE ROUTING	REQUIREMENT	WAVEFORM	VOLTAGE REQUIREMENT
3A	All cables within region 3A	Multiple Stroke Cable Bundle Shielded	1	250 I_r (Note 1)
3A	All cables within region 3A	Multiple Stroke Cable Bundle Shielded‘	3 (1 and 10 MHz)	250 V_L / 50 I_T
3A	All cables within region 3A	Multiple Stroke Cable Bundle Unshielded	4	125 V_T / 250 I_L (Note 2)
3A	All cables within region 3A	Multiple Stroke Cable Bundle Unshielded	3 (1 and 10 MHz)	250 V_T / 50 I_L (Note 2)
3A	All cables within region 3A	Multiple Burst Cable Bundle Shielded	3 (1 and 10 MHz)	250 V_L / 12.5 I_T
3A	All cables within region 3A	Multiple Burst Cable Bundle Unshielded	3 (1 and 10 MHz)	250 V_T / 12.5 I_L
3A	All cables within region 3A	Single Stroke Pin injection Shielded	4	125 V_{oc} / 25 I_{sc}
3A	All cables within region 3A	Single Stroke Pin injection Shielded	3 (1 MHz)	250 V_{oc} / 10 I_{sc}
3A	All cables within region 3A	Single Stroke Pin injection Unshielded	4	125 V_{oc} / 25 I_{sc} (28 Volt power wire - 750 V_{oc} / 150 I_{sc})
3A	All cables within region 3A	Single Stroke Pin injection Unshielded	3 (1 MHz)	250 V_{oc} / 10 I_{sc} (28 Volt power wire - 1500 V_{oc} / 60 I_{sc})

Note 1: Assume 25 A per shielded twisted pair or low impedance wire to a maximum of 250 A.

Low impedance wire is defined as any wire with an impedance of 100 ohms or less at frequencies below 10KHz.

Note 2: When testing power leads as a separate cable, ensure that corresponding short circuit current (Isc) in each power is not exceeded.

General Notes:

a. Shielded Cable Bundle is defined as cable bundle which contains one or more shields. Such cable bundle may contain some unshielded wires.

b. Unshielded Cable Bundle is defined as a cable bundle which contains no shields

c. Pin Injection shielded refers to the test level applicable to a shielded wire

d. Pin Injection unshielded refers to the test level applicable to an unshielded wire

e. V_T represents the test voltage level in volts and I_T represents the test current level in amperes.

f. V_L and I_L represent the voltage and current limits intended to prevent over-stressing the EUT beyond requirements.

g. V_{oc} and I_{sc} represent the open circuit voltage and short circuit current respectively

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

TABLE 6. Lightning Indirect Effects: Lightning EM Region 3B ETDL Cables Routed Within The Avionics Rack

REGION	CABLE ROUTING	REQUIREMENT	WAVEFORM	VOLTAGE REQUIREMENT
3B	All cables within region 3B	Multiple Stroke Cable Bundle Shielded	1	100 I_T (Note 1)
3B	All cables within region 3B	Multiple Stroke Cable Bundle Shielded	3 (1 and 10 MHz)	100 V_L / 20 I_T
3B	All cables within region 3B	Multiple Stroke Cable Bundle Unshielded	4	50 V_T / 100 I_L (Note 2)
3B	All cables within region 3B	Multiple Stroke Cable Bundle Unshielded	3 (1 and 10 MHz)	100 V_T / 20 I_L (Note 2)
3B	All cables within region 3B	Multiple Burst Cable Bundle Shielded	3 (1 and 10 MHz)	100 V_L / 5 I_T
3B	All cables within region 3B	Multiple Burst Cable Bundle Unshielded	3 (1 and 10 MHz)	100 V_T / 5 I_L
3B	All cables within region 3B	Single Stroke Pin injection Shielded	4	50 V_{oc} / 10 I_{sc}
3B	All cables within region 3B	Single Stroke Pin injection Shielded	3 (1 MHz)	100 V_{oc} / 4 I_{sc}
3B	All cables within region 3B	Single Stroke Pin injection Unshielded	4	50 V_{oc} / 10 I_{sc} (28 Volt power wire - 750 V_{oc} / 150 I_{sc})
3B	All cables within region 3B only	Single Stroke Pin injection Unshielded	3 (1 MHz)	100 V_{oc} / 4 I_{sc} (28 Volt power wire - 1500 V_{oc} / 60 I_{sc})

Note 1: Assume 10 A per shielded twisted pair or low impedance wire to a maximum of 100 A.

Low impedance wire is defined as any wire with an impedance of 100 ohms or less at frequencies below 10KHz.

Note 2: When testing power leads as a separate cable, ensure that corresponding short circuit current (Isc) in each power wire is not exceeded.

General Notes:

a. Shielded Cable Bundle is defined as cable bundle which contains one or more shields. Such cable bundle may contain some unshielded wires.

b. Unshielded Cable Bundle is defined as a cable bundle which contains no shields

c. Pin Injection shielded refers to the test level applicable to a shielded wire

d. Pin Injection unshielded refers to the test level applicable to an unshielded wire

e. V_T represents the test voltage level in volts and I_T represents the test current level in amperes.

f. V_L and I_L represent the voltage and current limits intended to prevent over-stressing the EUT beyond requirements.

g. V_{oc} and I_{sc} represent the open circuit voltage and short circuit current respectively

TABLE 7. Lightning Indirect Effects: Lightning EM Region 3C ETDL Cables Routed Within the Fuselage Pressure Vessel Except EM Regions 3A and 3B

REGION	CABLE ROUTING	REQUIREMENT	WAVEFORM	VOLTAGE REQUIREMENT
3C	All cables within this region	Multiple Stroke Cable Bundle Shielded	1	600 I_T (Note 1)
3C	All cables within this region	Multiple Stroke Cable Bundle Shielded	3 (1 and 10 MHz)	600 V_L / 120 I_T
3C	All cables within this region	Multiple Stroke Cable Bundle Unshielded	4	300 V_T / 600 I_L (Note 2)
3C	All cables within this region	Multiple Stroke Cable Bundle Unshielded	3 (1 and 10 MHz)	600 V_T / 120 I_L (Note 2)
3C	All cables within this region	Multiple Burst Cable Bundle Shielded	3 (1 and 10 MHz)	600 V_L / 30 I_T
3C	All cables within this region	Multiple Burst Cable Bundle Unshielded	3 (1 and 10 MHz)	600 V_T / 30 I_L
3C	All cables within this region	Single Stroke Pin injection Shielded	4	300 V_{oc} / 60 I_{sc}
3C	All cables within this region	Single Stroke Pin injection Shielded	3 (1 MHz)	600 V_{oc} / 24 I_{sc}
3C	All cables within region 3B	Single Stroke Pin injection Unshielded	4	300 V_{oc} / 60 I_{sc} (28 Volt power wire - 750 V_{oc} / 150 I_{sc})
3C	All cables within region 3B only	Single Stroke Pin injection Unshielded	3 (1 MHz)	600 V_{oc} / 24 I_{sc} (28 Volt power wire - 1500 V_{oc} / 60 I_{sc})

Note 1: Assume 60 A per shielded twisted pair or low impedance wire to a maximum of 600 A.

Low impedance wire is defined as any wire with an impedance of 100 ohms or less at frequencies below 10KHz.

Note 2: When testing power leads as a separate cable, ensure that corresponding short circuit current (Isc) in each power wire is not exceeded.

General Notes:

a. Shielded Cable Bundle is defined as cable bundle which contains one or more shields. Such cable bundle may contain some unshielded wires.

b. Unshielded Cable Bundle is defined as a cable bundle which contains no shields

c. Pin Injection shielded refers to the test level applicable to a shielded wire

d. Pin Injection unshielded refers to the test level applicable to an unshielded wire

e. V_T represents the test voltage level in volts and I_T represents the test current level in amperes.

f. V_L and I_L represent the voltage and current limits intended to prevent over-stressing the EUT beyond requirements.

g. V_{oc} and I_{sc} represent the open circuit voltage and short circuit current respectively

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

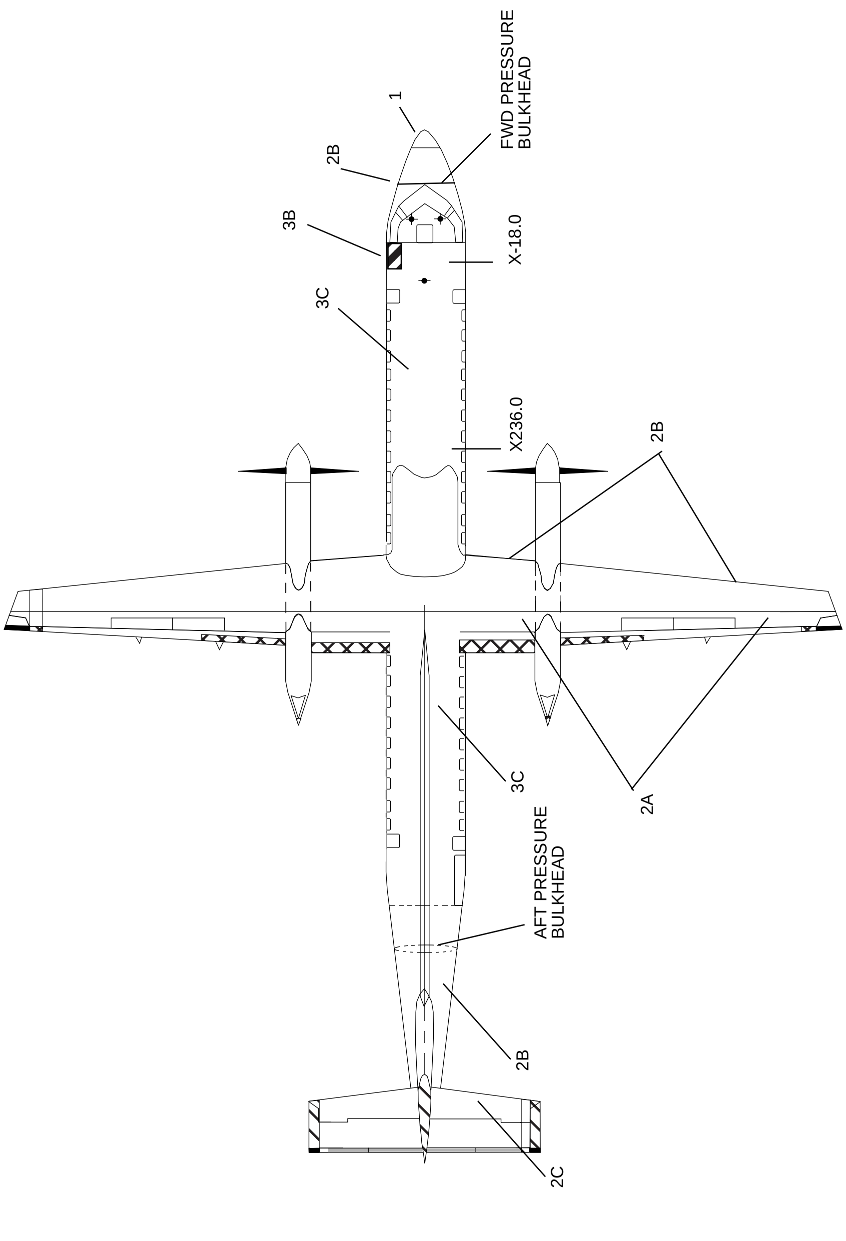

FIGURE 1. Lightning EM Regions

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

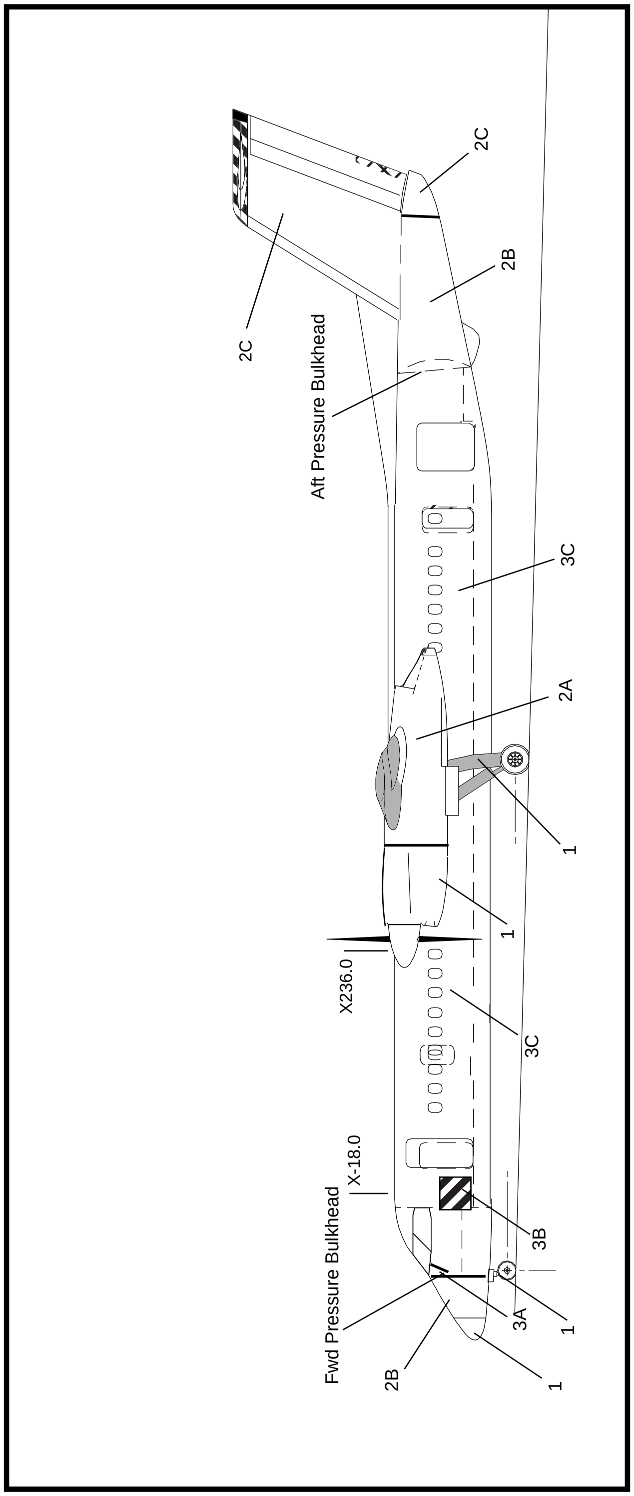

FIGURE 2. Lightning EM Regions

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

1.6.3 Lightning Verification Testing

1.6.3.1 Pin Testing

If a cable is routed in more than one lightning EM region, the pin injection test shall utilize the levels associated with the most severe Lightning EM Region (Refer to Figure 15).

When the “remote end” load impedance for the pin under test is specified in the equipment installation requirements, that impedance characteristic may be inserted in series with the test generator and equipment under test. To account for cable frequency effects, the maximum inserted series impedance shall be limited to 75 ohms during Waveform 3 testing, resulting in a maximum source impedance of 100 ohms. It must also be demonstrated by test that the remote end load impedance can withstand the appropriate voltage and current levels.

For simple equipment/components, such as electromechanical devices temperature probes sensors, etc., where the circuits are electrically isolated from case and local airframe grounds, a dielectric withstand or hi-pot test to the peak amplitude of the pin injection ETDL levels shall be adequate to satisfy pin injection requirements. These equipment/components shall be tested to the Multiple Stroke and Multiple Burst requirements as part of the system test.

1.6.3.2 Cable Bundle Testing

If a cable harness is routed within more than one lightning EM region, the total length of cable bundle shall simultaneously be tested to the current level consistent with the environment in which each segment of the cable bundle is routed (refer to Figure 15).

The cable bundle test for complex systems as shown in Figure 15 may be simplified using the guidelines as illustrated in Figure 16. In addition, if the length of the cable harness used for testing is shorter than the aircraft cable harness installation, the magnitude of the lightning test current must be increased accordingly.

> *Example:* If the length of the cable used for the lightning cable bundle test is one half the length of the aircraft cable bundle, then the level of the lightning cable bundle test current must be two times the level specified in Tables 1 to 7.

Cable bundle testing (Multiple Stroke and Multiple burst) must be carried out with the second level of shielding disconnected at both ends. (The second level of shielding refers to the overall shield which is applied to critical systems wiring routed outside the fuselage pressure vessel).

Each cable bundle shall be tested excluding ground wires (associated with the equipment under test) which are grounded to structure locally to the equipment. The cable bundle test requirements are satisfied by applying the specified waveforms and levels (Tables 1-7) to interconnecting cable bundles simultaneously.

Primary power lines shall be tested as a separate cable with the test current being injected and monitored on each line.

1.6.3.3 Test Requirements

Multiple Stroke Testing

Multiple stroke testing requires the application of 24 pulses spaced randomly in a 2 second time period. The first pulse is the full amplitude ETDL as defined in the cable bundle tests above. The remaining 23 pulses are one quarter (1/4) the amplitude of the first pulse for waveform 1and one half (1/2) the amplitude of the first pulse for waveforms 2 and 3. The multiple stroke pulse train is applied 10 times at each polarity. Multiple stroke testing is carried out using Ground Injection or Cable Induction techniques as outlined in RTCA DO160C Section 22 (June 19, 1992 or later issue).

Multiple Burst Testing

Multiple burst testing requires the application of 3 bursts of 20 pulses each. The interval between bursts shall be between 30 and 300 milliseconds. The time between individual pulses within a burst shall be between 50 and 1000 microseconds (see Figures 10 and 11). The multiple burst test shall be applied for a long enough period of time (5-10 minutes at each polarity) to ensure interaction with equipment operation (clock frequency etc.). Multiple burst testing is carried out using Cable Induction techniques as outlined in RTCA DO160C Section 22 (June 19, 1992 or later issue).

Multiple Stroke and Multiple Burst testing shall be carried out closed loop on a completely operational system. Testing shall commence at low amplitude levels and progressively increase to the qualification

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

test levels. The system Supplier must carry out a “systems test” on all equipment comprising the system including interconnecting cable harnesses manufactured by both the equipment Supplier and airframe manufacturer. Any interfacing equipment which may be the responsibility of “other” equipment Suppliers must be included in the test or electrically simulated. The Supplier is responsible for fabricating the cable harness required for certification testing. Multiple Stroke and Multiple Burst testing shall be carried out as required by FAA AC 20-136.

The laboratory test set-up shall represent all aspects of the aircraft installation including cable bundle composition (including shields and shield terminations), installation policy, and equipment bonding techniques.

The system shall be tested in the various operational states (including input sensors) to ensure the system is evaluated at its maximum sensitivity.

Pin Injection Testing

Pin Injection testing requires the application of 10 transients of each polarity to the connector pins of the equipment under test. Upon completion of pin testing verify that any protective devices within the equipment have not been damaged and operationally verify that the equipment meets performance specifications. Pin Injection testing shall be carried out in accordance with RTCA DO 160C section 22 (June 19, 1992 or later issue).

1.6.4 Test Program

The Supplier shall provide a test plan defining the test procedures, proof of test article conformity and any supporting information to be used to demonstrate compliance with the Lightning requirements. Test article conformity includes a controlled layout drawing to document all the electrical and mechanical details of the test article including the test harness and equipment comprising the test article. Any deviation form the aircraft installation must be documented. The test results shall be documented by the Supplier and provided to de Havilland. Any and all observable effects exhibited by the equipment during testing shall be reported to the de Havilland and the acceptability of these effects shall be agreed upon by de Havilland.

1.6.5 External Lightning Environment

1.6.5.1 Indirect Effects

The components which are important for electrical/electronic systems Indirect Effects assessment are Current Waveforms A, D/2 and H. The external threat definition for these waveforms is defined below.

Component A possesses a peak current of 200000 amperes and a peak rate of rise at t=0+ of 1.4 x 10^{11} amperes per second and 1.0 x 10^{11} amperes per second at t=0.5 x 10^{-6}.

Each pulse is defined by the following double exponential expression:

$$I(t)=Io\ (e^{-at}-e^{-bt})$$

where the constants for the Component A pulse are defined as follows:

Io= 218 810 amperes

a= 11 354 $seconds^{-1}$

b= 647 265 $seconds^{-1}$

t= time seconds

Component D/2 possesses a peak current of 50000 amperes and a rate of rise of 0.5 x 10^{11} amperes per second at t=0.25 x 10^{-6}.

Each pulse is defined by the following double exponential expression:

$$I(t)=Io\ (e^{-at}-e^{-bt})$$

where the constants for the Component D/2 pulse are defined as follows:

Io= 54 703 amperes

a= 22 708 $seconds^{-1}$

b= 1 294 530 $seconds^{-1}$

t= time seconds

Component H possesses a peak current of 10000 amperes and a peak current rate of rise at t=o+ seconds of 2 x 10^{11} amperes per second.

Each pulse is defined by the double exponential expression:

$$I(t)=Io\ (e^{-at}-e^{-bt})$$

where the constants for the Component H pulse are defined as follows:

Io= 10 572 amperes

a= 187 191 $seconds^{-1}$

b= 19 105 100 $seconds^{-1}$

t= time seconds

1.7 Electromagnetics Protection

1.7.1 Electrical Bonding and Grounding

Unless otherwise specified by de Havilland or the Supplier, all electrical and electronic equipment must be electrically bonded to the aircraft structure through direct metal to metal contact. To ensure a low impedance bond between the equipment case and the aircraft structure, the electrical bonding shall be accomplished through direct metal to metal contact of the equipment case, mounting trays and racks, shelf brackets and aircraft structure.

The equipment case shall include the equipment connector and backshell and any part of the equipment exterior shell or housing which encloses the internal electrical/electronic or other functional parts. The Supplier shall verify the electrical bonding of all equipment by means of an electrical bonding functional test procedure. The electrical bonding test procedure and results for each component shall be documented by the Supplier and provided to de Havilland.

Electrical bonds between equipment case and aircraft structure and between various components of the equipment case shall not exceed a maximum resistance of 0.0025 ohms. Bonding straps may only be used where authorized and must be reviewed on a case by case basis. RF bonding straps must be as short as possible and provide a low impedance bond throughout the RF frequency range. RF bond straps shall have a maximum length to width ratio of 5 to 1.

The Supplier shall refer to ESP 84 for more detailed electrical bonding standards.

1.7.2 Protective Devices

The use of protective devices (diodes, tranzorbs, etc.) to protect against electromagnetic effects shall be minimized if alternative means are available. The functional readiness of such protective devices, if used, shall be verifiable. The Supplier shall provide de Havilland with Quality Control and Maintenance procedures for supplied equipment to ensure that the initial condition of the design features is adequate and to verify their integrity in service. In the case of active protective devices that are an integral part of the Supplier equipment, there is a need to check the integrity of the devices at suitable intervals since these devices are subject to random failures that may be hidden during normal operation.

1.7.3 Shielding

Electrical and electronic system wiring shall be designed and protected to meet the Electromagnetic requirements outlined in paragraphs 1.1 - 1.6. The Supplier in cooperation with de Havilland shall define cable shield and shield termination requirements (including such requirements that apply to de Havilland supplied wiring that interfaces with the Suppliers wiring/equipment) that may be required to ensure that the electrical and electronic systems meet the Electromagnetic requirements outlined in paragraphs 1.1 - 1.6.

All parts of the electromagnetic protection system including electrical bonding interfaces, shields, shield terminations, electrical connectors, equipment cases and protective devices must be protected against the effects of corrosion and must be shown to be verifiable and maintainable for the life of the installation. For systems which perform critical functions, the Supplier shall specify the maximum allowable degradation of cable shield and connector transfer impedances in order to maintain compliance with the Electromagnetic requirements of paragraphs 1.1 - 1.6.

1.7.4 Electrostatic Discharge Susceptibility (ESD)

Equipment which performs critical and essential functions shall not experience any component failure and shall not exhibit a response which is detrimental to aircraft safety or result in any effect which

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

will cause flight crew action, complaints or passenger concerns when subjected to the following test.

The equipment shall comply with the requirements outlined above when subjected to electrostatic discharges which represent a typical personnel discharge of 100 picofarads at 15000 volts.

Adjust the ESD generator to 15000 volts. Slowly scan the discharge probe over the surface of the equipment applying one discharge per second (NOTE: DO NOT APPLY TO CONNECTOR PINS). The equipment shall be tested in the powered and unpowered state. During the powered state, the tests shall be carried out for each operating mode of the system. Both polarities of the transient shall be applied. The test setup and waveform are shown in figures 12, 13 and 14.

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

TABLE 8. LEVEL A CERTIFICATION TEST LEVELS

FREQUENCY (Hz)	CERTIFICATION PEAK (V/m)	CERTIFICATION AVERAGE (V/m)	CERTIFICATION AVERAGE (mA)
10 -100 K			3 - 30
100 - 500 K			30 - 150
500 K - 2 M			150
2 - 30 M			150
30 - 70 M			150
70 - 100 M			150
100 - 200 M		100	150
200 - 400 M		100	150
400 - 700 M	400	100	
700 M - 1 G	700	100	
1 - 2 G	650	100	
2 - 4 G	900	100	
4 - 6 G	850	100	
6 - 8 G	250	100	
8 - 12 G	900	100	
12 - 18 G	450	100	

TABLE 9. LEVEL A NORMAL TEST LEVELS

FREQUENCY (Hz)	NORMAL PEAK (V/m)	NORMAL AVERAGE (V/m)	NORMAL AVERAGE (mA)
10 - 100 K			1.5 - 15
100 - 500 K			15 - 75
500 K - 2 M			75
2 - 30 M			75
30 - 70 M			75
70 - 100 M			75
100 - 200 M		50	75
200 - 400 M		50	75
400 - 700 M	400	30	
700 M - 1 G	100	30	
1 - 2 G	450	50	
2 - 4 G	800	50	
4 - 6 G	600	80	
6 - 8 G	150	80	

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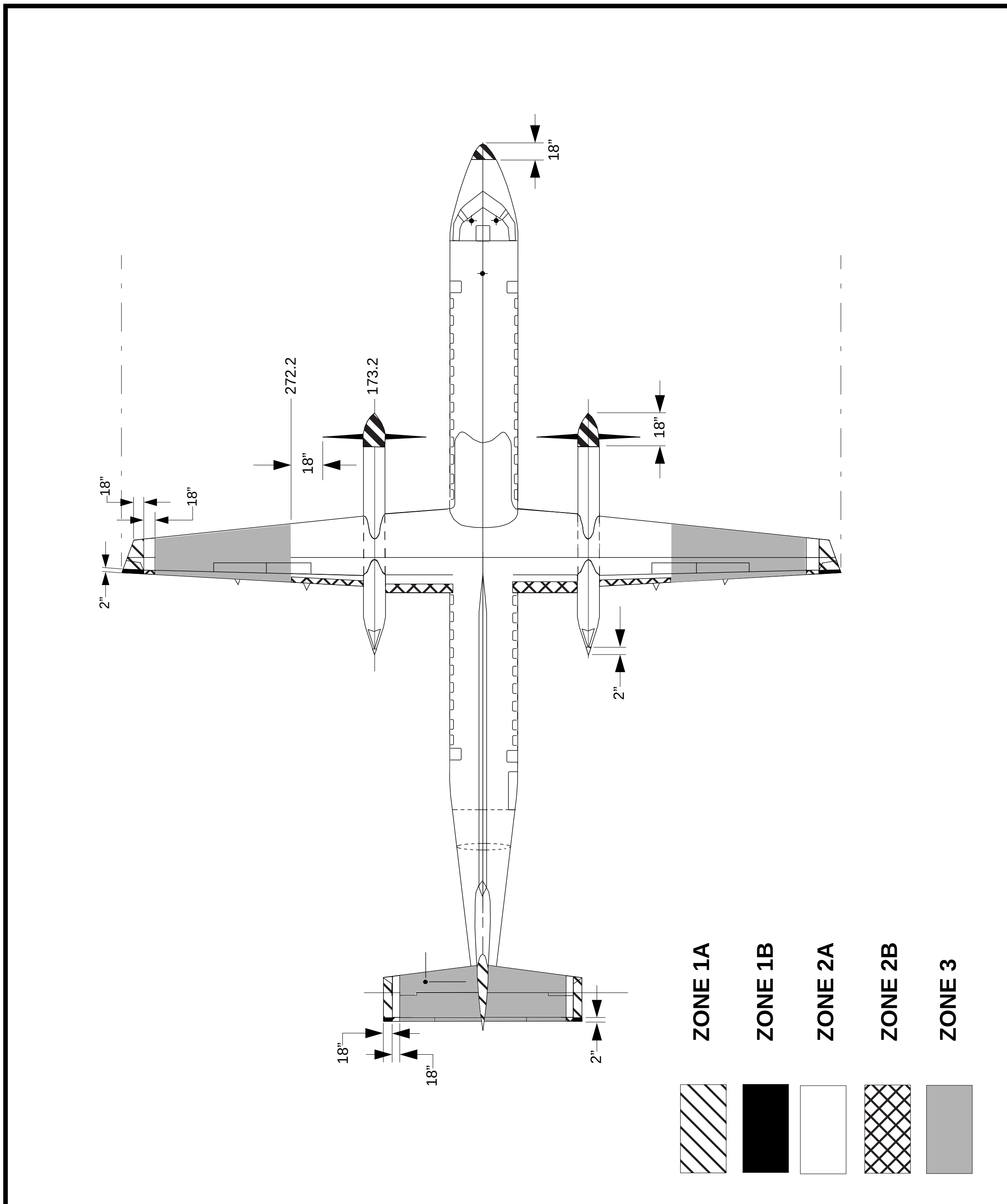

FIGURE 3. Probable Lightning Strike Distribution

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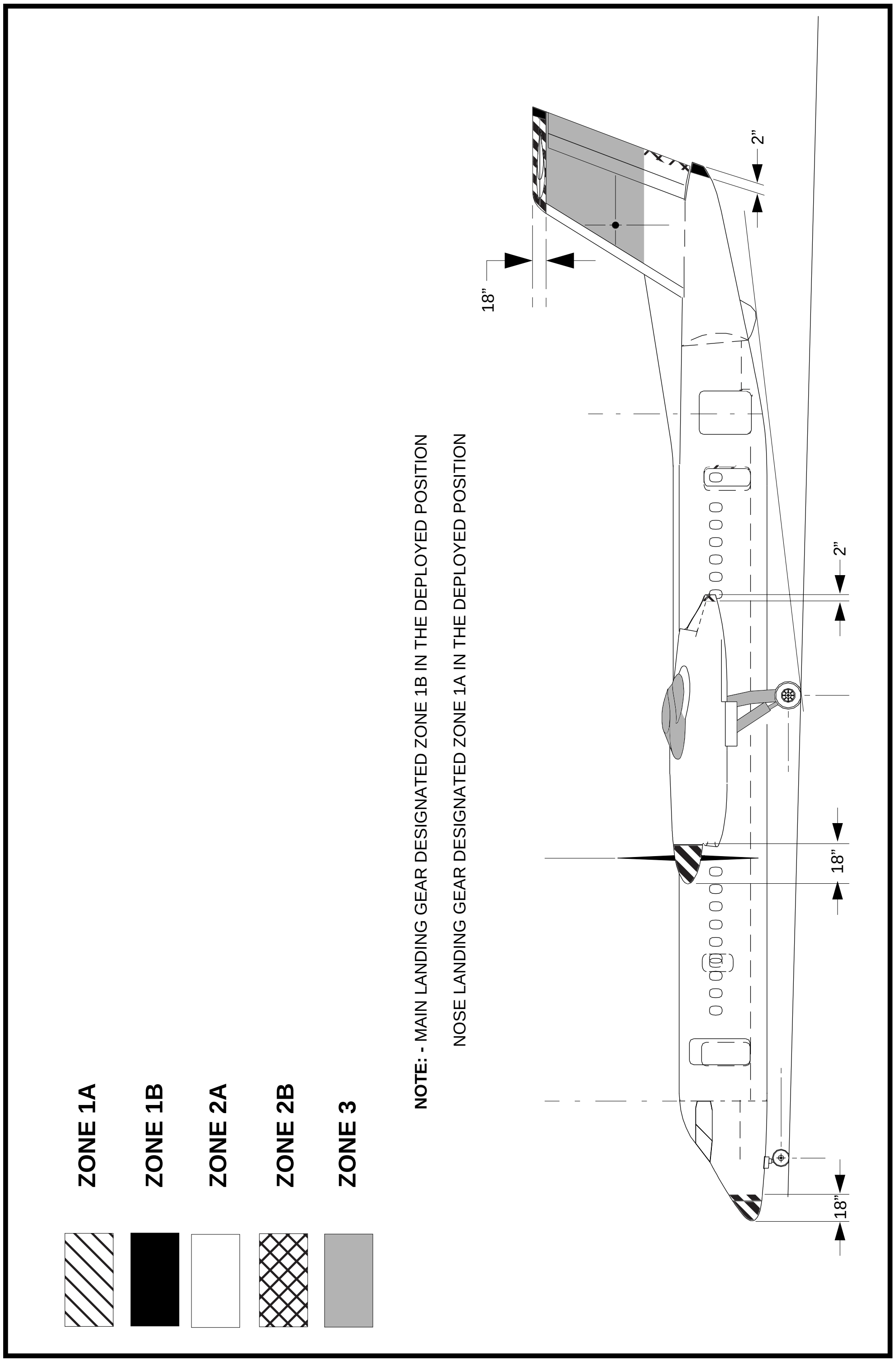

FIGURE 4. Lightning Strike Zones - Dash-8 Series 400; Side View

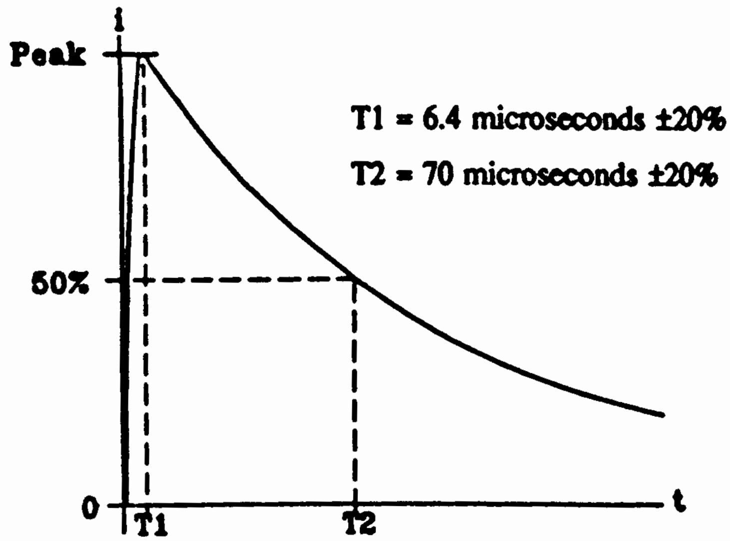

FIGURE 5. Current Waveform 1

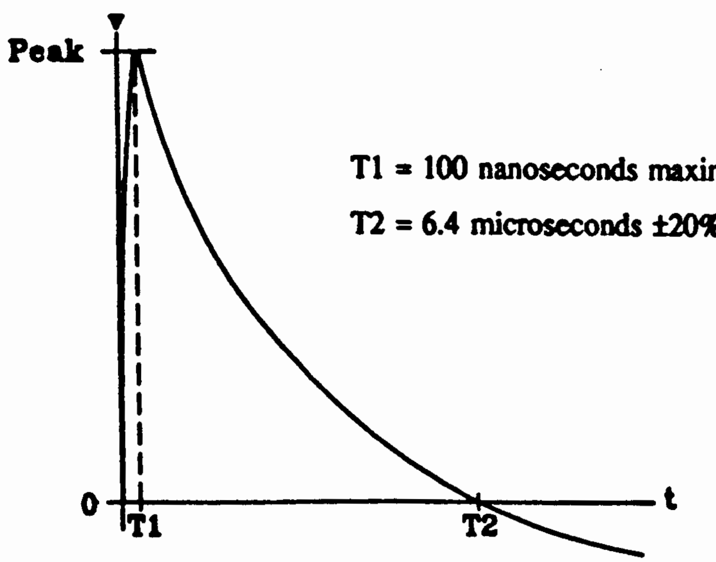

FIGURE 6. Voltage Waveform 2

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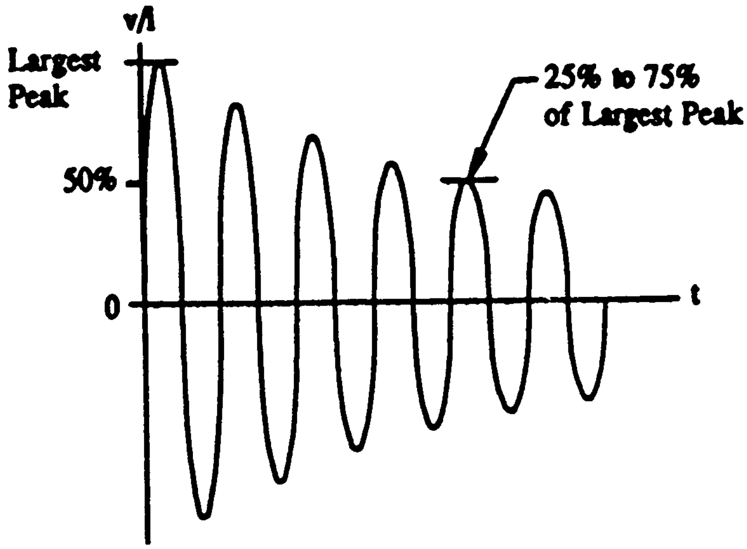

FIGURE 7. Voltage/Current Waveform 3

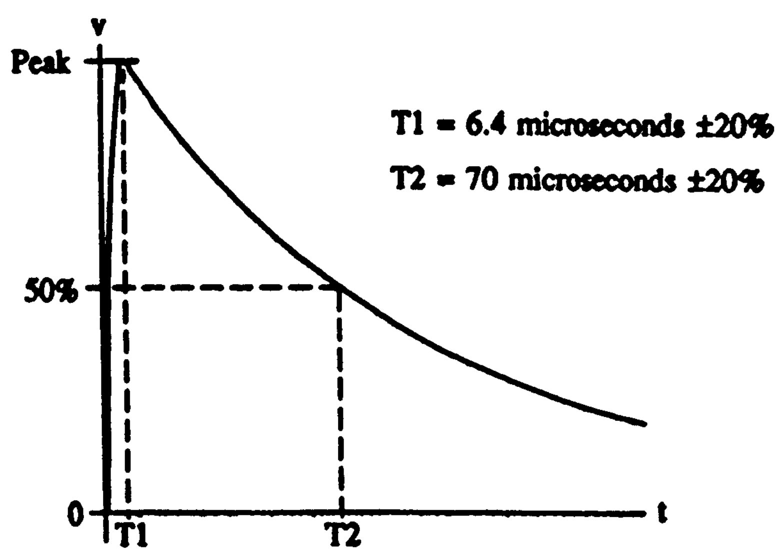

FIGURE 8. Voltage Waveform 4

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

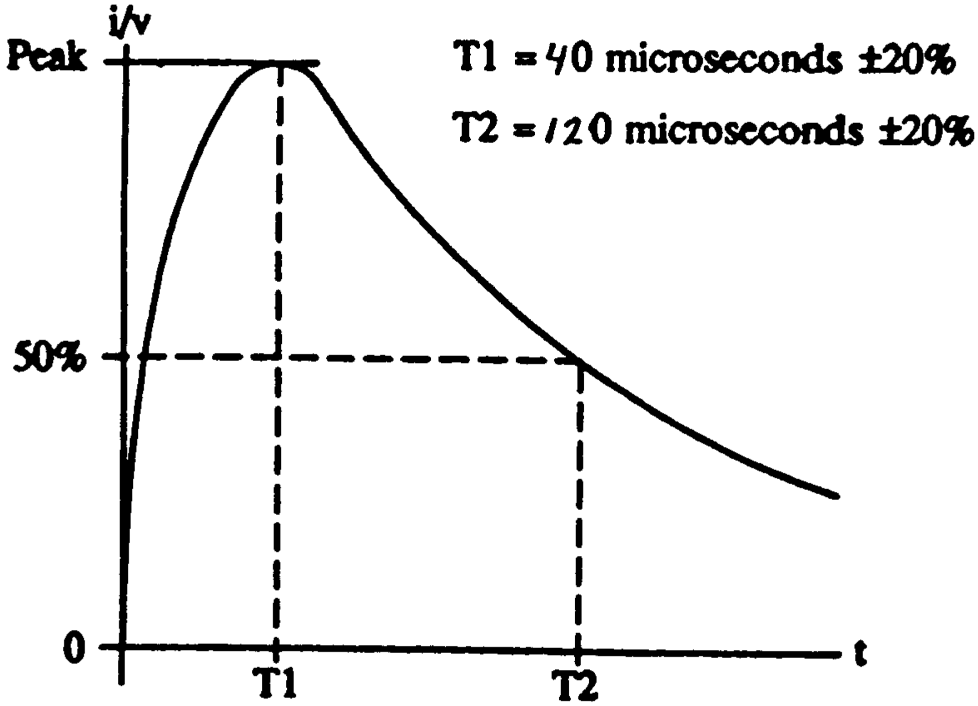

FIGURE 9. Current/Voltage Waveform 5A

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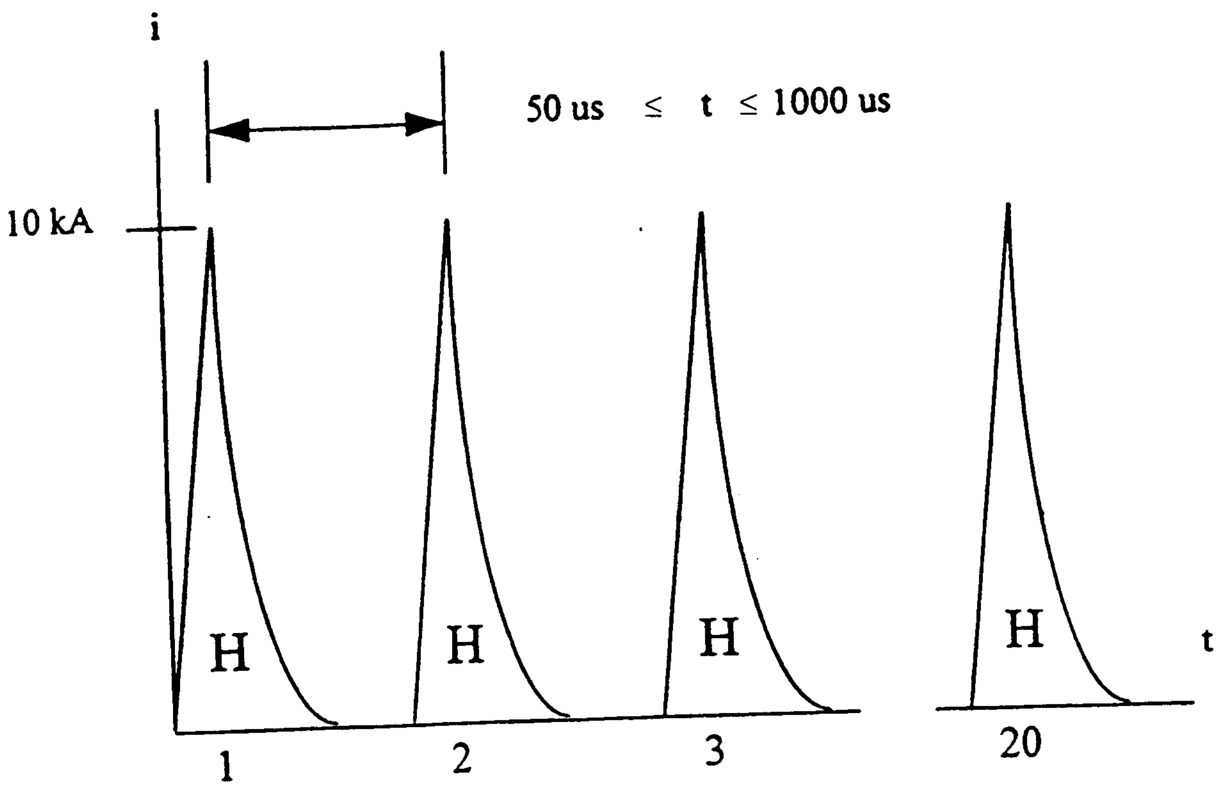


FIGURE 10. Burst Components

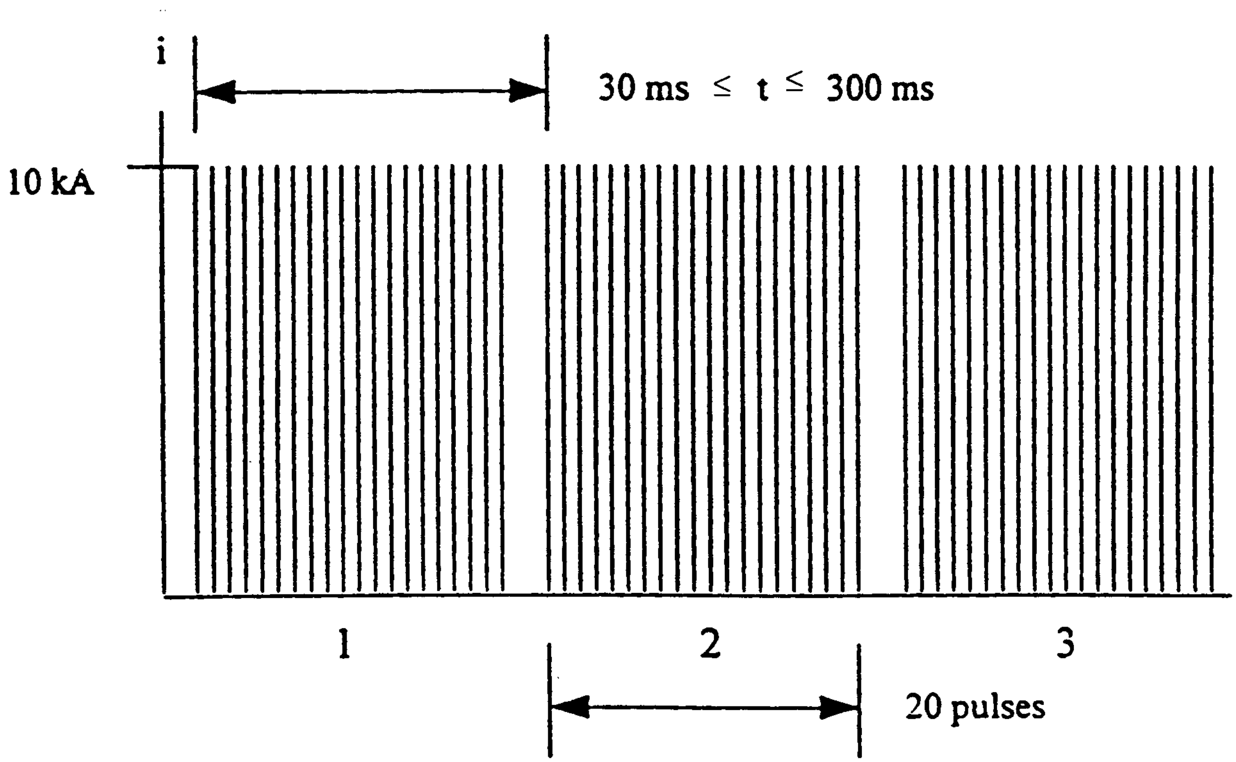


FIGURE 11. Multiple Burst Waveform

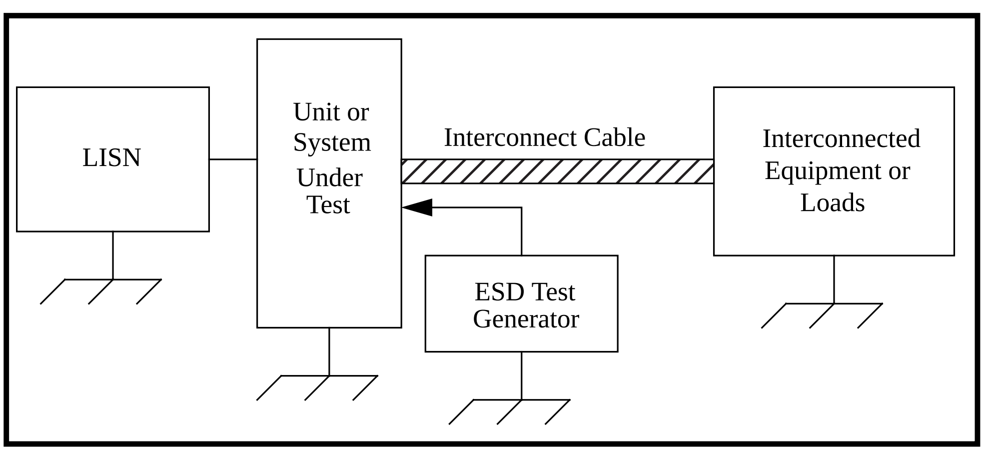


FIGURE 12. Electrostatic Discharge (ESD) Test Setup

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

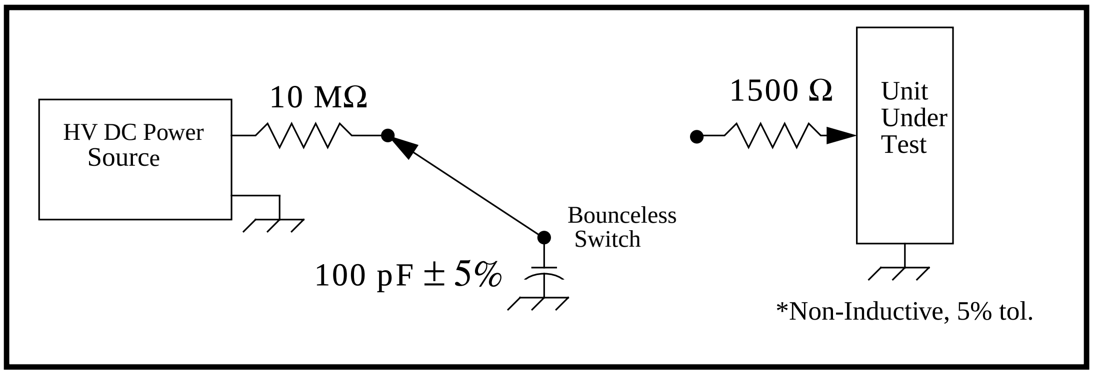
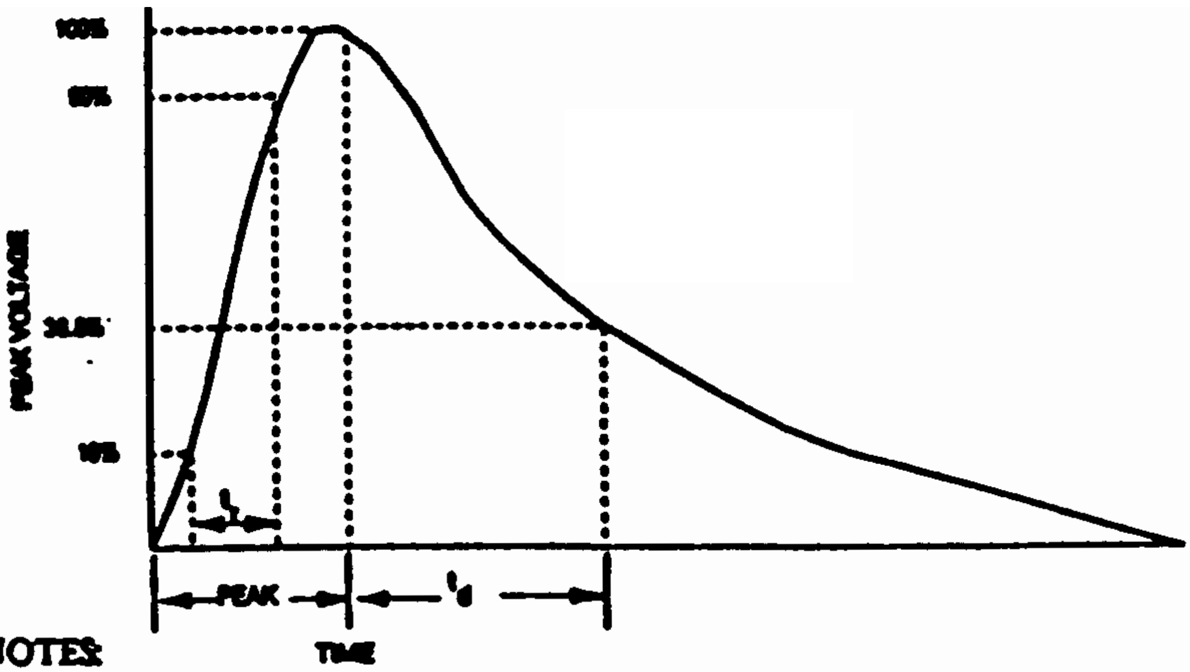


FIGURE 13. Electrostatic Discharge (ESD) Test Generator



NOTES:

1. The rise time (tr) of the pulse voltage (Vp) shall be measured from 10% to 90% of the peak amplitude, V peak, and shall not exceed 15 nanoseconds (ns).
2. The pulse decay (t_d) shall be approximately 150 ns.
3. Test Voltage: V = 15000

FIGURE 14 . ESD Test Voltage Wavefor m

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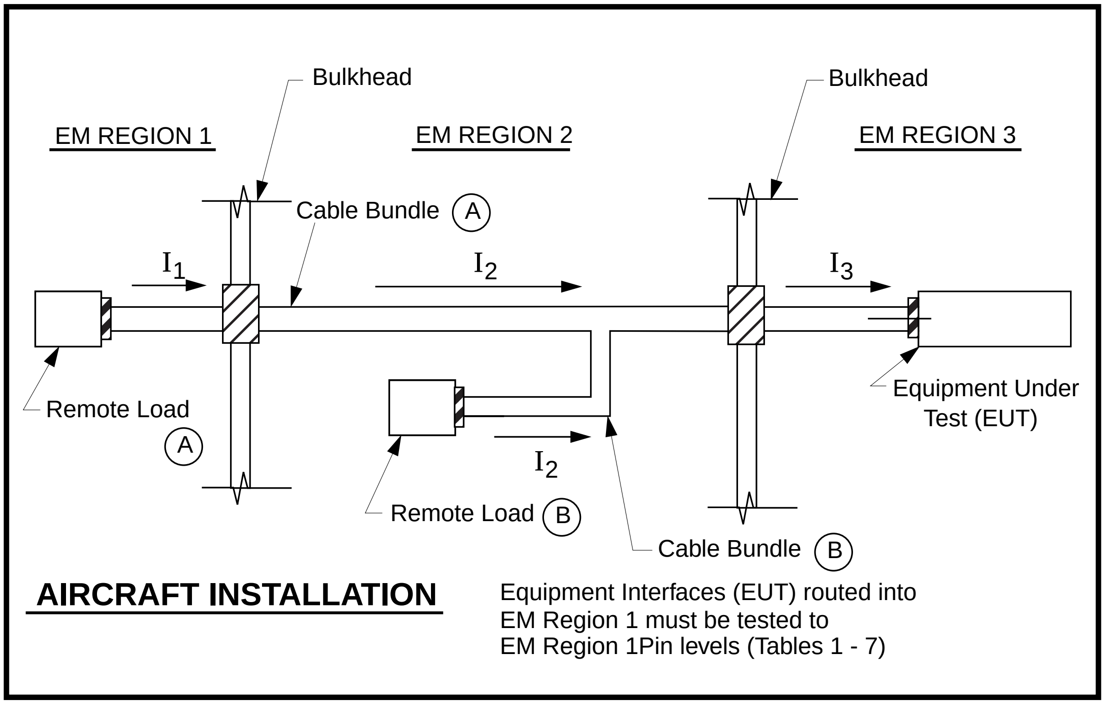
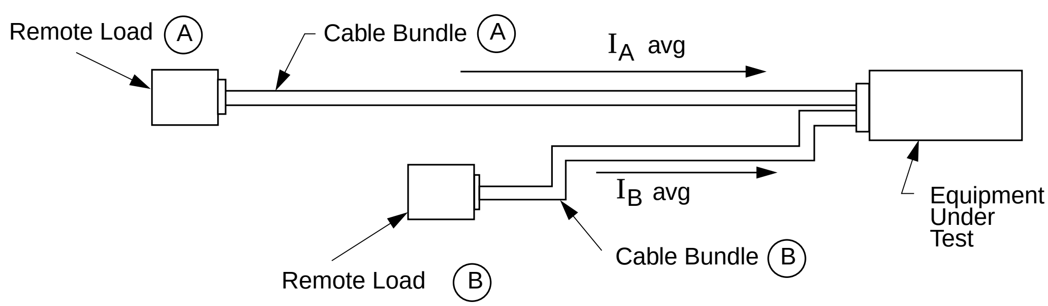


FIGURE 15. EM Region Interfaces

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS REQUIREMENT DHC-8 SERIES 400 ELECTRICAL/ ELECTRONIC SYSTEMS AND EQUIPMENT

The aircraft cable bundle installation shown in Figure 15 may be simplified for the cable bundle test using the proposed setup in Figure 16

NOTE: The test cable harness must be fabricated with any disconnect that utilizes Pigtail Shield Terminations.



$$I_A \text{ avg} = \frac{I_1 L_1 + I_2 L_2 + I_3 L_3}{L_1 + L_2 + L_3}$$

- where L_1, L_2, L_3 represent the cable bundle lengths in each lightning EM Region

$$I_B \text{ avg} = \frac{I_2 L_2 + I_3 L_3}{L_2 + L_3}$$

- where I_1, I_2, I_3 represent the cable bundle current levels in each EM Region

FIGURE 16. Proposed Set-up of Cable Bundle Test